

# Design Issues for the RHIC EBIS\*

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**Abstract.** Promising results are currently being obtained on the BNL Electron Beam Test Stand (EBTS), which is a prototype for the Relativistic Heavy Ion Collider (RHIC) EBIS. Based on the present results, a proposal has been made regarding the general design of the RHIC EBIS. During the next year experiments will be made to investigate physics issues and beam properties important to the detailed design of the RHIC EBIS. Below we have outlined some of the physics issues to be explored experimentally, beam diagnostics that will be employed, and hardware modifications that are desired to go from the prototype stage to the RHIC EBIS.

## INTRODUCTION

In the course of developing an EBIS capable of delivering up to  $3.4 \times 10^9$   $\text{Au}^{32+}$  ions/pulse in a 10-40  $\mu\text{s}$  pulse, many choices have been made in design parameters. Based on the performance of existing EBISs at the start of our program, our previous experience with operating EBISs, and time constraints, a conservative approach was chosen for the RHIC EBIS concept, which we consider the most promising for producing the required ion charge. Based on our present results, and more or less in accordance with the original proposal [1], the RHIC EBIS will operate in a traditional EBIS mode, have a 1.5 m trap length, a warm bore, an unshielded superconducting solenoid, and utilize a 10 A, 20 keV electron beam with a current density  $< 600 \text{ A/cm}^2$ . The goal for ion yield will be reached if one achieves 50% neutralization of the electron beam by the ion species of interest and 20% of that charge is in the desired charge state; these are parameters which have been achieved in other EBISs.

Although the parameter choices present some difficulties in electron beam power dissipation in the electron collector, and in the maintenance of ultra-high vacuum in the trap region, it is believed that these problems can be solved in a rather straightforward manner. On the other hand, the chosen parameters have the advantage of placing relatively moderate demands on electron beam current density, ion charge state, and mechanical precision required. Our most recent experiments have been performed on a full power, half length prototype for the EBIS called EBTS. Excellent performance of the electron gun, designed and built at Novosibirsk [2], helped us to

complete electron beam tests early in the program, and allowed us to move quickly into ion production tests. EBTS operates in a pulsed mode for both the electron gun and the drift tube high voltages, which extends the operational range of our present 50 kW electron collector and also allows us to freely explore source parameters while at the same time maintaining the source ultrahigh vacuum. A detailed description of the EBTS design and present results [3], and a proposal for the EBIS-based RHIC preinjector [4] can be found elsewhere in these proceedings. The results so far have justified the approach taken, and we are confident that a working RHIC EBIS can be built which will be closely related to EBTS, but incorporating improvements based on experimental findings through the coming year.

## PHYSICS STUDIES

During the next few months work will continue on heavy ion production with externally injected cesium and gold ions. Earlier EBTS results with xenon at 4 A electron beam have demonstrated an ion yield corresponding to a 50% beam neutralization. However, since EBTS is not designed for gas injection, a long low charge state tail was observed, as expected. By using Cs ion injection, we were able to achieve narrow spectral distributions, with up to 20% charge abundance in a desired charge state. With external ion injection, EBTS operation is presently limited to an electron beam current of 3 A, imposed by power supply availability for the anode and drift tubes for the various trap configurations to be investigated.

During the coming year we expect to continue upgrading EBTS so that heavy ion production at 10 A can be demonstrated. Some of the investigations and source improvements to be made are outlined below. These are intended to answer some of the questions related to the detailed design of the RHIC EBIS.

- *Investigate the use of the solenoid fringing field for ion injection and/or ion trapping:* Can injection efficiency be increased? What are the tradeoffs, determined experimentally, between trap capacity and ion charge state distribution?
- *Experiment with the injection of solid gold in the fringe field of the solenoid:* In initial experiments a deflection of the electron beam will be used to evaporate gold from a wire. Can a good charge state distribution be achieved using this method, and how would it impact EBTS reliability?
- *Electron beam ramping studies:* Preliminary experiments have been made which demonstrate that one can avoid virtual cathode formation in the electron beam by allowing ion accumulation in the trap region. This can lower the requirements on drift tube voltages. What effect does ramping have on ion yield, charge state distribution, and emittance?
- *Ion injection studies with ramped electron beam/drift tube potentials:* Can ions be injected more effectively in a lower current electron beam?

- *Ion trapping and cooling studies:* Can other species be introduced in a controlled manner to improve the ion distribution and/or ion beam emittance? Can limiting neutralization of the electron beam by maintaining lower trap barrier electrodes enhance ion cooling?
- *Test an alternate electron beam platform configuration:* Presently, EBTS operates with the “collector supply” providing a negative bias to the cathode, while the collector is held at ground through a fault detection circuit, which shuts down the electron beam if excessive current is lost to other electrodes. This arrangement has several disadvantages: 1) if the protection fails the collector supply is capable of delivering the full electron beam current to a location other than the collector, 2) the electron beam launch is sensitive to the cathode bias, requiring very good regulation of the “collector supply”, and 3) the electron beam energy in the trap region and at the collector are controlled by the same supply. Operating in this mode was necessary to accommodate the available “collector supply”, but for reliable operation of the RHIC EBIS we shall purchase a new supply. One will then be able to configure the EBIS in the standard mode. In particular, the collector supply would determine the electron beam collection energy, whereas a second low current (~10 mA) supply would bias the electron gun/collector platform and determine the beam energy in the trap region. In this case, collector power supply regulation requirements would be greatly reduced, possibly resulting in a large cost savings for this ~15 A, 15 kV collector supply.
- *Test smaller drift tube diameter:* Operation of EBTS with a 32 mm drift tube diameter has been very successful. Will one see adverse effects on electron beam propagation and ion confinement for smaller drift tube diameters, e.g. 10mm? If not, smaller diameters will reduce high voltage requirements on drift tubes.
- *Test the introduction of lossy ceramics in vicinity of drift tube gaps:* Is there any evidence of improved electron beam or ion beam stability with the introduction of RF absorbers in the EBTS. (At present the EBTS electron beam is relatively quiet).
- *Reflex EBIS mode operation:* Experiments will be done at Dubna and on EBTS on ion production with “electron strings”. This collaboration with E. Donets is through a grant from the Civilian Research and Development Foundation.
- *Studies of energy deposition on a mockup of the new electron collector:* The design of a new collector for RHIC EBIS will be verified at EBTS before proceeding with manufacturing.

## DIAGNOSTICS

As we come closer to achieving our goals on ion yield, characterization of the EBTS heavy ion beams through the use of profile and emittance monitors will become important in preparation for transmission of the beam through the RFQ. The following diagnostics will be tested and installed on EBTS during the next 6 months:

- A new Mamyrin-type time-of-flight diagnostic, for use with up to 30 kV ion beams. This device is similar to our existing spectrometer, and will be able to resolve individual charge states of gold, centered around 35+. A retarding grid is incorporated into the new TOF system to provide energy analysis.
- An inline TOF will be built to accept the total beam and provide a low resolution analysis of the ion beam components.
- A beam current transformer will be installed for non-destructive measurement of the total ion beam current. The feasibility of using a current transformer in conjunction with the inline TOF will also be examined, enabling one to monitor the charge state distribution for each pulse transmitted to the RFQ.
- A harp for ion beam profile measurement will be installed. This is especially useful for optimizing and monitoring the ion injection process.
- An emittance monitor will be installed for measuring both the ion injector and EBIS extracted ion beams.

## HARDWARE ISSUES

Several of the major components of the RHIC EBIS are: a 15 A electron gun, a 230 kW electron collector, a 15 kV, 15 kA collector supply, and 2 m long, 8" warm bore superconducting solenoid. Other major items include transport optics for the high current ion beam and an auxiliary ion source suitable for producing gold ions. Some of these aspects have been presented in Reference 4. Additional hardware considerations include the following:

- *Control system:* Improvements/additions are required to the EBIS drift tube voltage and timing controller. Provide an external trigger to enable synchronization with the line frequency and accelerator devices. Install sampled ADC readbacks on electron beam related optics. Monitor the behavior of the source during various EBIS subcycles. Enable unattended running of the EBIS with DC beams for HV training/cleaning. Prepare interlocks that shut off beams and drift tube HV supplies for equipment protection.
- *Vacuum related:* The vacuum design should be such that it insures reliable operation. The design should provide convenient baking capabilities, and one

should operate the source at moderate current ( $\sim 1\text{-}2$  A DC) to provide source cleaning.

- *Mechanical:* To provide fast turnaround times and make servicing the source easier, the source should be composed of modular sections, with as few re-entrant sections as possible.
- *HV Platforms:* There are several options for obtaining high voltage ion extraction from the EBIS for injection into the RFQ. One could provide fast pulsing ( $\sim 100\mu\text{s}$ ) of the drift tubes up to 50-60 kV. In this case one might also have to elevate the electron gun and collector platform to avoid losing the radial ion trap. This scheme has the advantage of keeping the source shell at ground potential. Alternatively, one could place the entire EBIS on a high voltage platform so that the EBIS operation remains unchanged.

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